Bornholm Test Island

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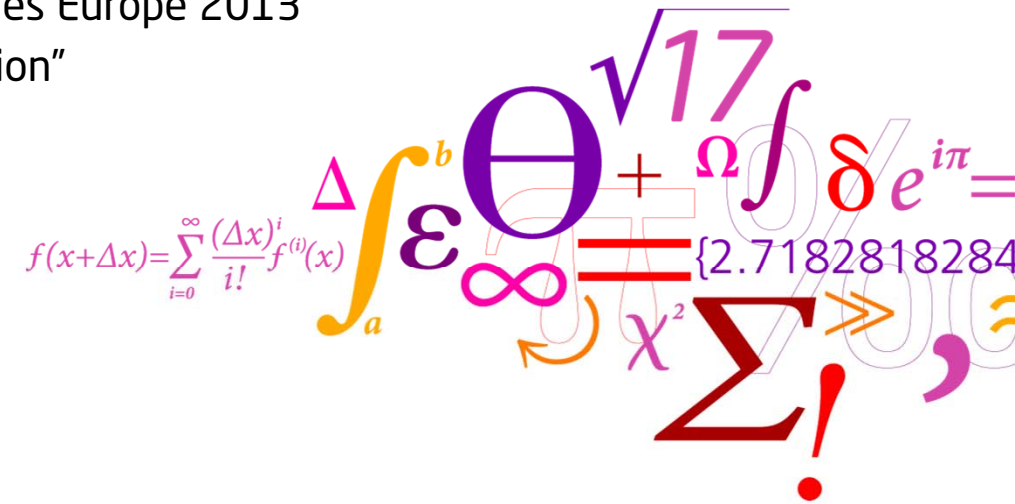
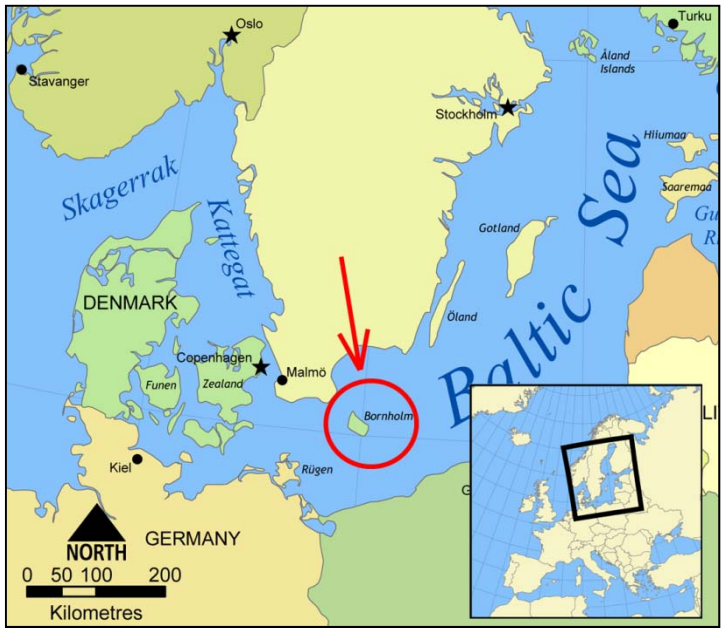


DTU Electrical Engineering
Department of Electrical Engineering

Bornholm Island as Full-Scale Laboratory

1% of Denmark



BRIGHT GREEN ISLAND

BORNHOLM

- Area: 589 m2
- Population: 40.715 (13.730 in Rønne)
- Largest company: Jensen Group, industrial laundry technology

- Strong political vision & public commitment
- Energy strategy 2008
- Tradition within energy since 1980's

Ref: K. Jørgensen et al., *Energy Plan for a Green Island: Project for Renewable Energy at Bornholm*, Borgen, ISBN 8741879112 9788741879116, 1986 (in Danish)

Bornholm Energy System

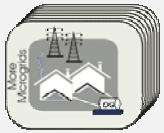
>30% wind power penetration

- Electricity demand, ~28,000 cust., 55 MW peak
  - Heat pumps roll-out
  - Electric vehicles
- Power generation
  - 29 MW wind power (modern/conventional)
  - 5 MW Solar PV (>1,000 units)
  - 2 MW biogas plant
  - 16 MW CHP plant (wood chips + coal), 35 MJ/s
  - 25 MW peak thermal power (fuel oil)
  - 10x1.5+19 MW backup units (diesel)
- Distribution grid
  - 60 kV / 10 kV / 0.4 kV
  - 16 main substations / 1,006 secondary subst.
- Part of the Nordic system
  - 60 kV under sea cable to Sweden, islanding
  - Nord Pool market (DK2)
- District heating
  - 5 systems, 560 GWh/year
  - CHP + straw-fired boilers

Bornholm Smart Grid Activities

Active distribution networks

- More Micro Grids (EU FP6)
- IDE4L (EU FP7) NEW



Solar PV integration

- PV Island Bornholm I+II+III
- PV Net

Electricity market designs

- EcoGrid EU (EU FP7) EcoGrid eu www.eu-ecogrid.net
- Flex Power

Customers and demand flexibility

- Smart Grid customer information
- Demand as frequency controlled demand

Electric Vehicle Integration

- EDISOIN EDISON

Wind power integration

- Coordinated Frequency Control of Wind Turbines in Power Systems

PowerLabDK

Strong National and International Collaboration
Examples of partners

- ***Energy companes:***

ØSTKRAFT energi til gode oplevelser (DK)
ENERGINET.DK (DK)
edp (PT)
ENERGIMIDT (DK)
elia Powering a world in progress (BE)
eandis (BE)
danskenergi (DK)

- ***Industrial partners etc.:***

IBM (CH)
SIEMENS (DE)
Danfoss (DK)
Landis+Gyr manage energy better (CH)
Vestas. (DK)
VESTFROST SOLUTIONS (DK)
(DK)
EURISCO RESEARCH & DEVELOPMENT (DK)

- ***Academic Partners:***

DTU (DK)
SINTEF (NO)
TNO innovation for life (NL)
AIT AUSTRIAN INSTITUTE OF TECHNOLOGY TOMORROW TODAY (AT)
EnCT (GE)
ECN (NL)

PowerLabDK combines experimental facilities

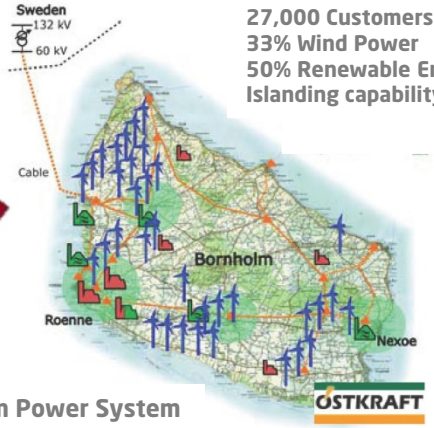
Flexible multi-purpose laboratories

Lyngby &
Ballerup Campus

Large-scale test system

Risø Campus

Full-scale Realistic Power System



27,000 Customers
33% Wind Power
50% Renewable Energy
Islanding capability

Bornholm Power System

Stakeholders:

ABB · nkt cables · dansk energi · SIEMENS · DONG energy · VATTENFALL · ENERGINET.DK · Vestas · IBM

Supported by:

GREEN LABS DK · EUDP

Investment:

18 million Euro

PowerLabDK

Intelligent Control Lab

Power system simulation, control and supervision

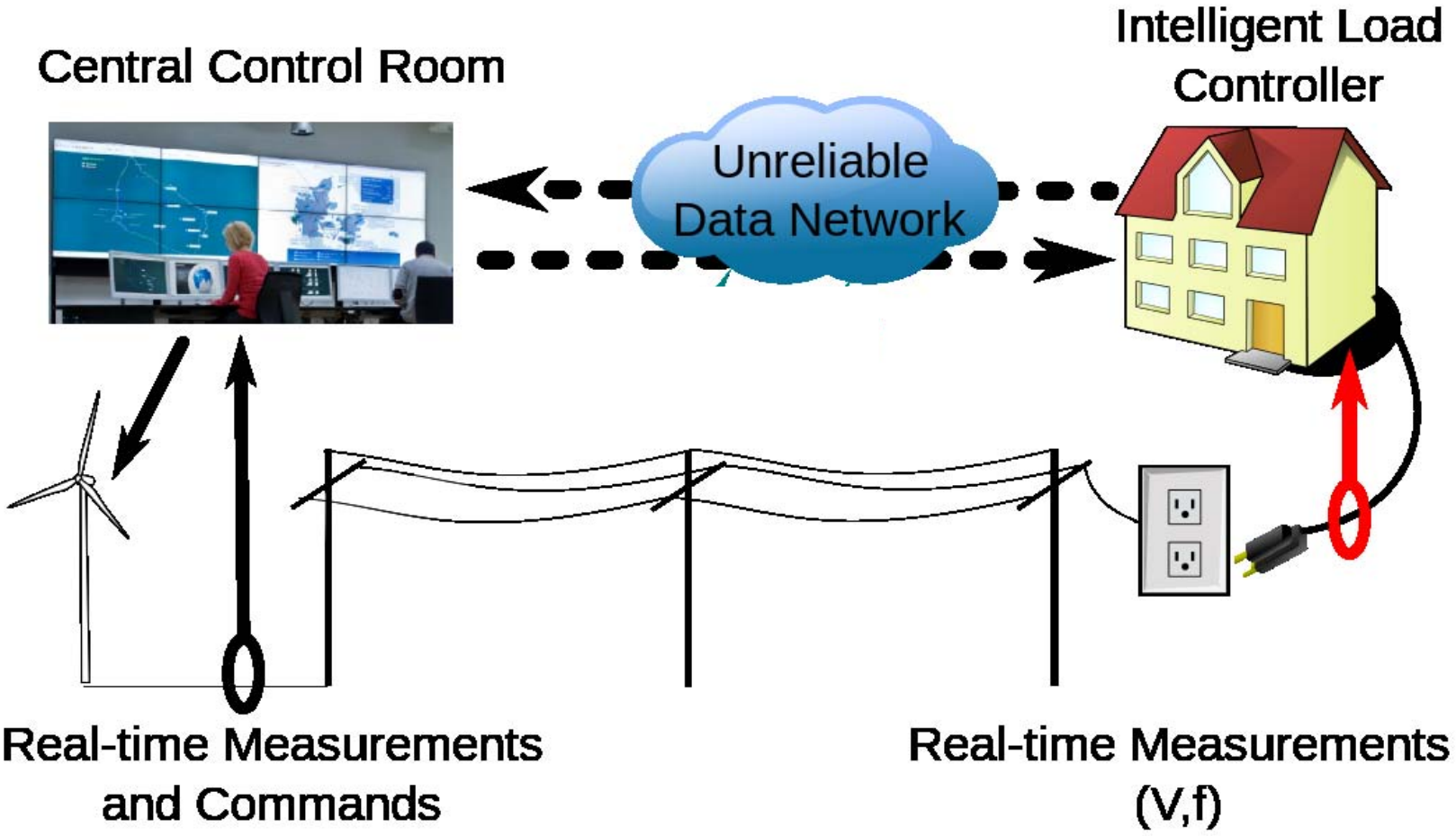
www.powerlab.dk

DTU Technical University of Denmark

INGENIØR HØJSKOLEN KØBENHAVN – University College

ØSTKRAFT
energi til gode oplevelser

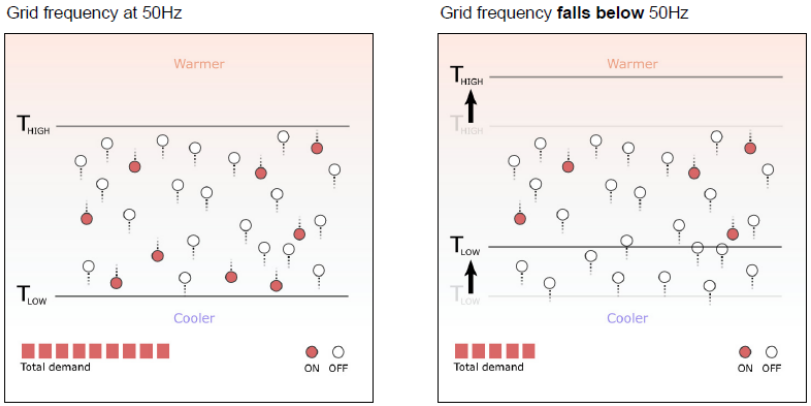
Autonomous V- and f-services from demand



System Reserves Provided by Frequency Responsive Electricity Demand

- **Field test with 200 residential, commercial and industrial demand units**

- Frequency reserves costs 8.000-22.000 €/MW/year in DK
- Pay pack time: **1-2½ year** w/ 1 kW unit



$$T_{high} = T_{high}^{normal} - kf\,(f - f_0)$$

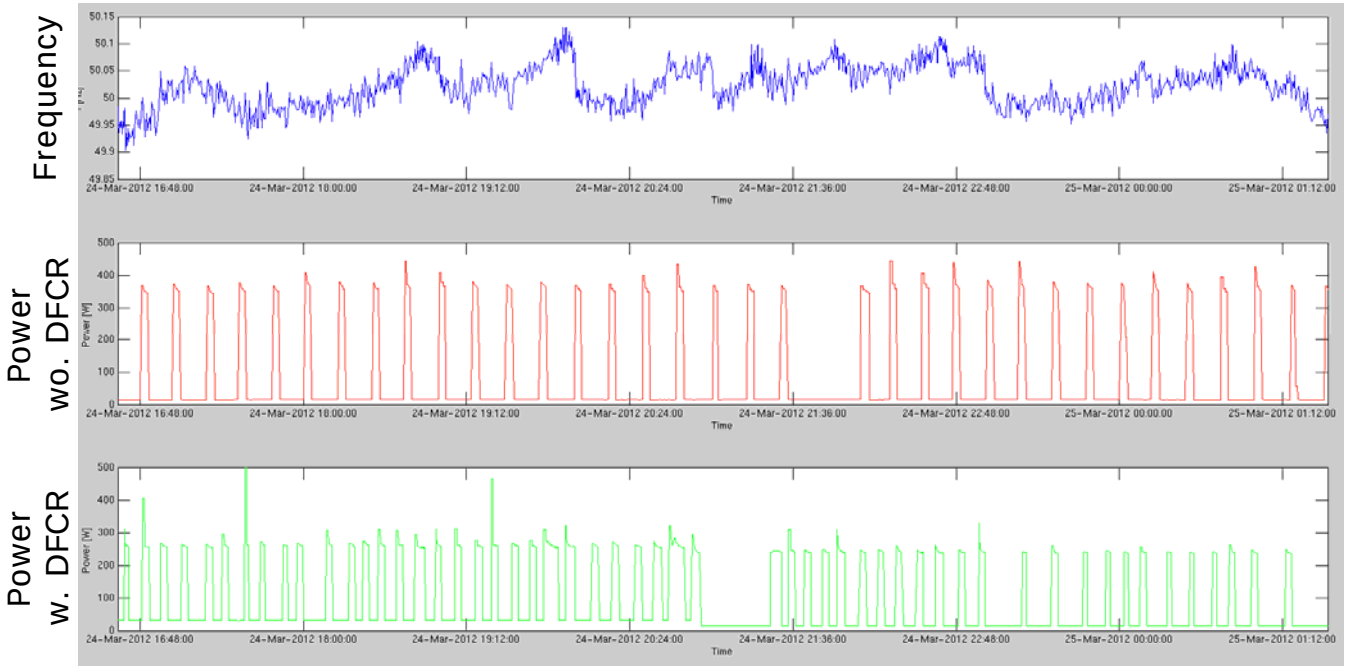
$$T_{low} = T_{low}^{normal} - kf\,(f - f_0)$$

Field test at Bornholm

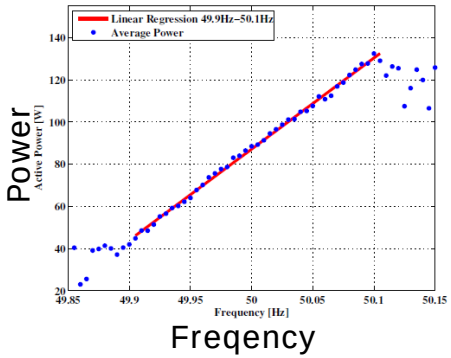
System Reserves Provided by Frequency Responsive Electricity Demand

Field measurements

Operation of a single bottle cooler



Delivery of normal reserve (49.9-50.1 Hz)



Delivery of disturbance reserve (<49.9 Hz)

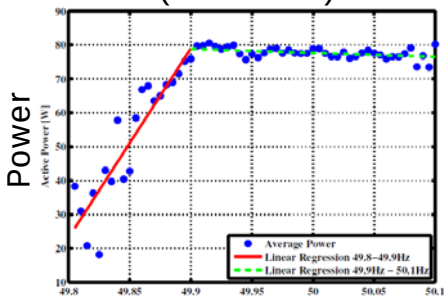


Figure 9. Frequen ng as a disturbance reserve, shown with egression in regions above and below 49.90 Hz.

- Demand can with maintained energy service deliver reserves which today are delivered by large power plants
- Easy implementation supporting commercialization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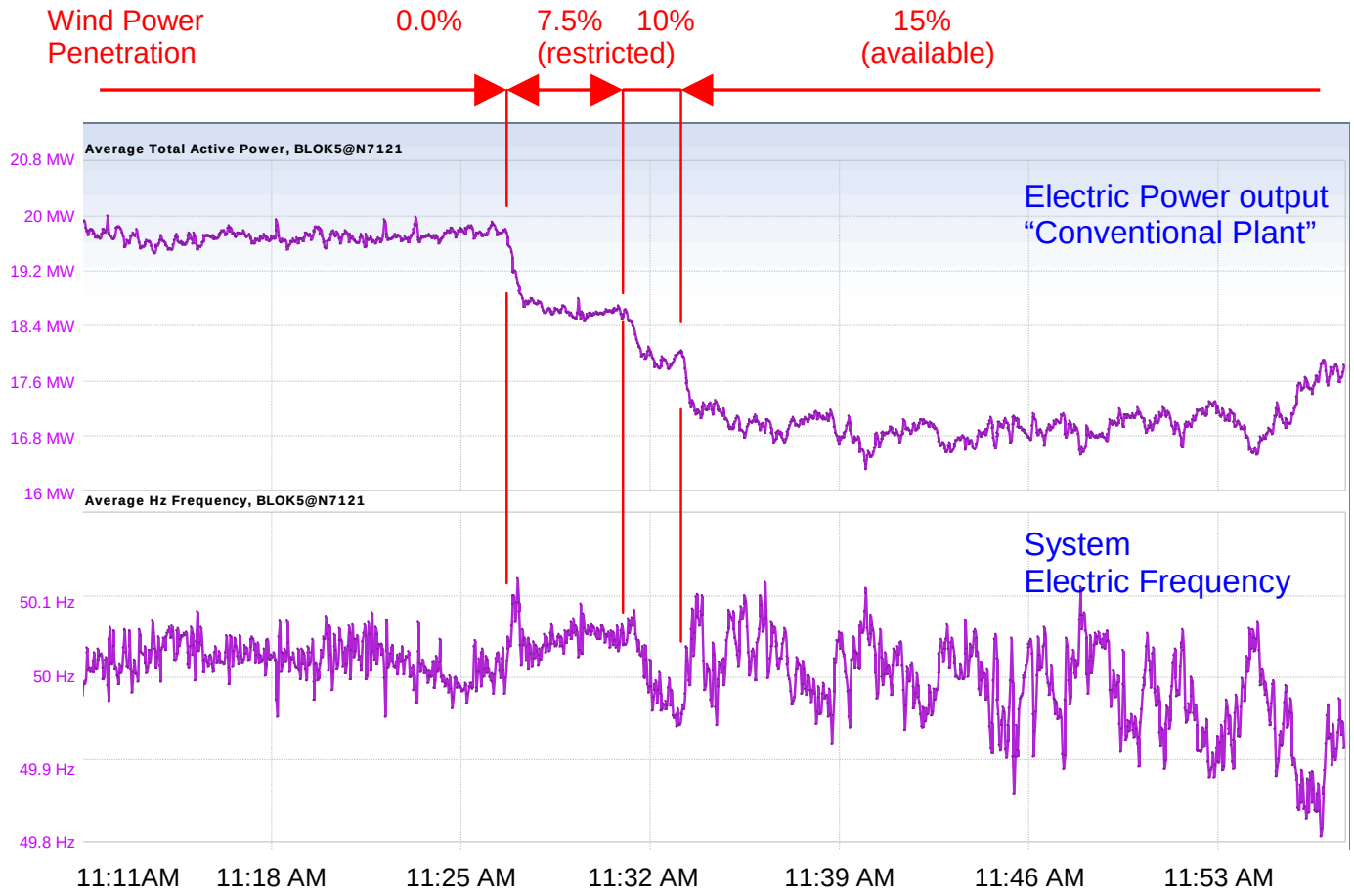
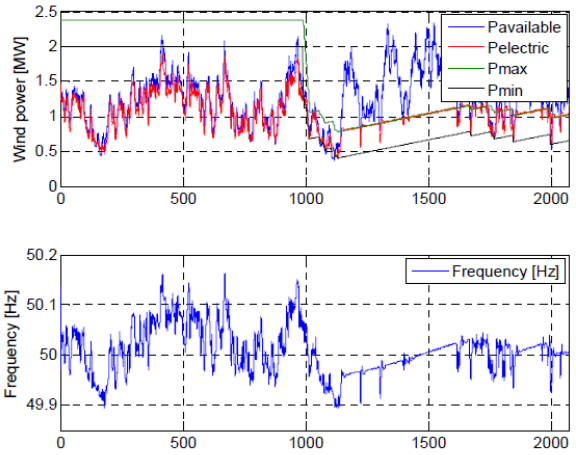
Island Operation of Bornholm

Experiment 17 September 2009

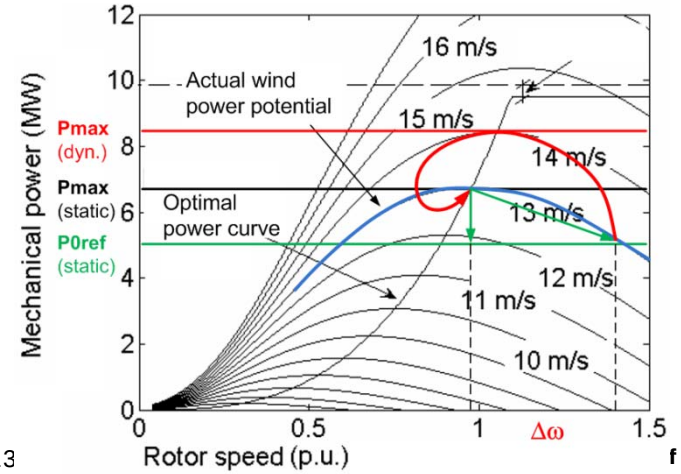


Coordinated Frequency Control by Wind Turbines

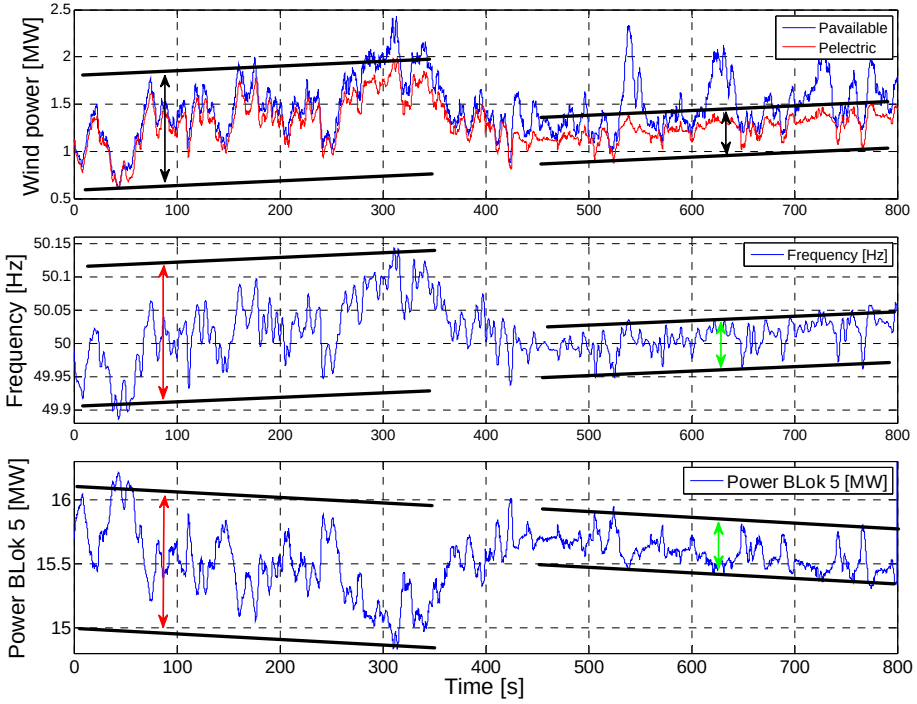
a) Fluctuation limiter



b) Transient static



Vestas®
No.1 in Modern Energy

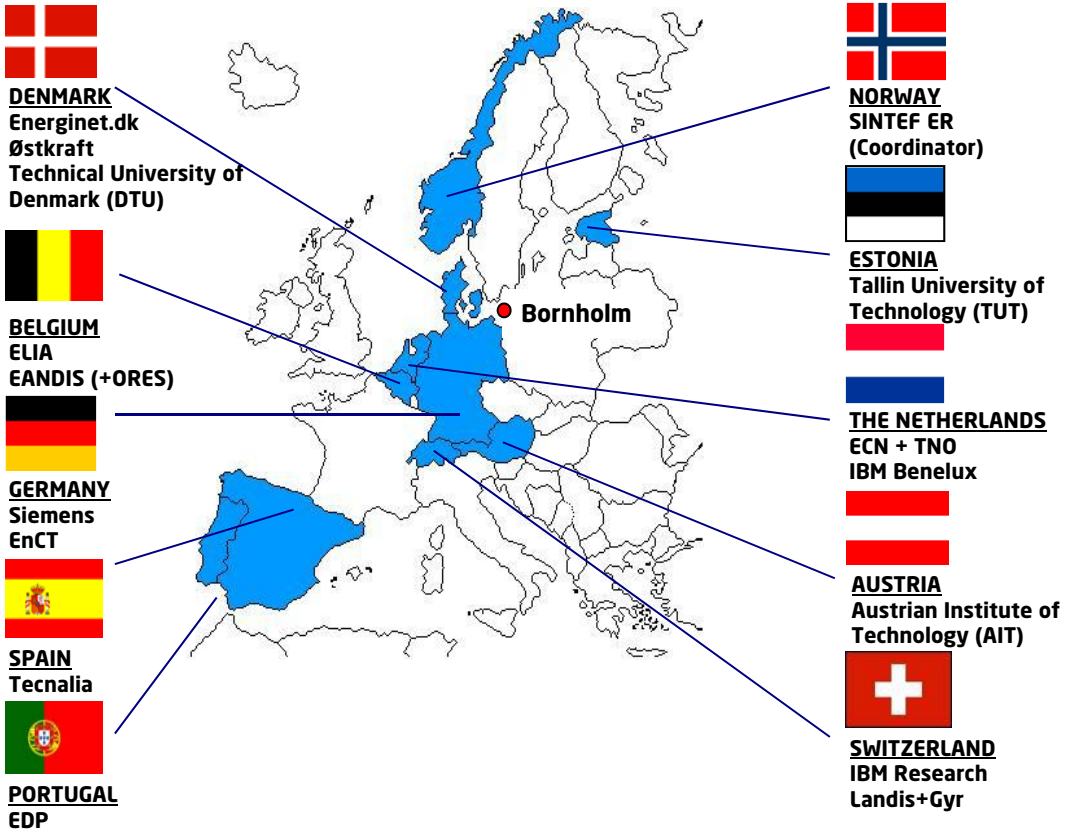


Ref: IEEE PES General Meeting, Calgary, Alberta, Canada, 2009.

EcoGrid EU

Large-scale demonstration of the future intelligent distribution system

- EU FP7 ENERGY
- 2011-14
- Budget: 21 million Euro
- Integrated research and demonstration
- ~2,000 active customers
- EU fast-track to Smart Grids

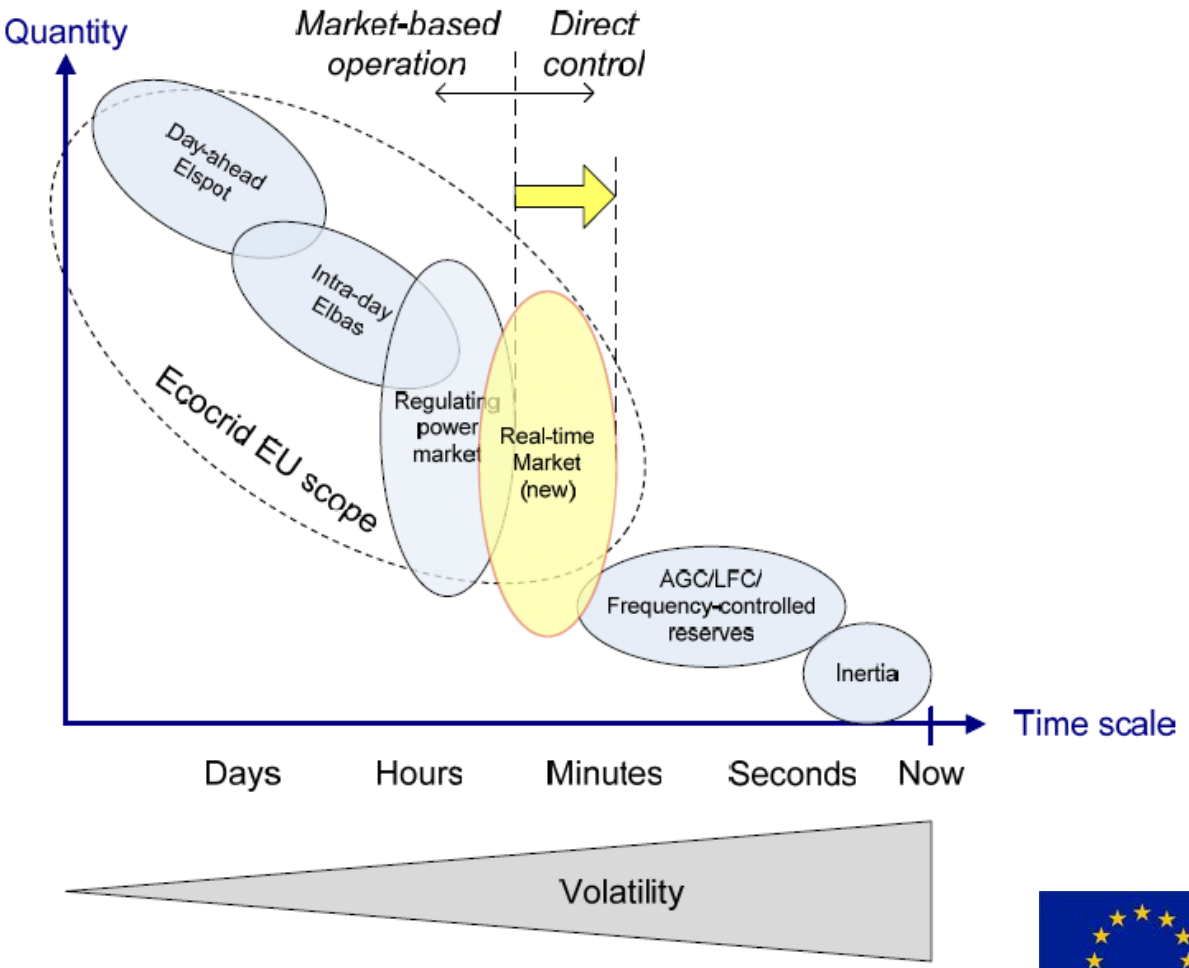


SUSTAINIA 100

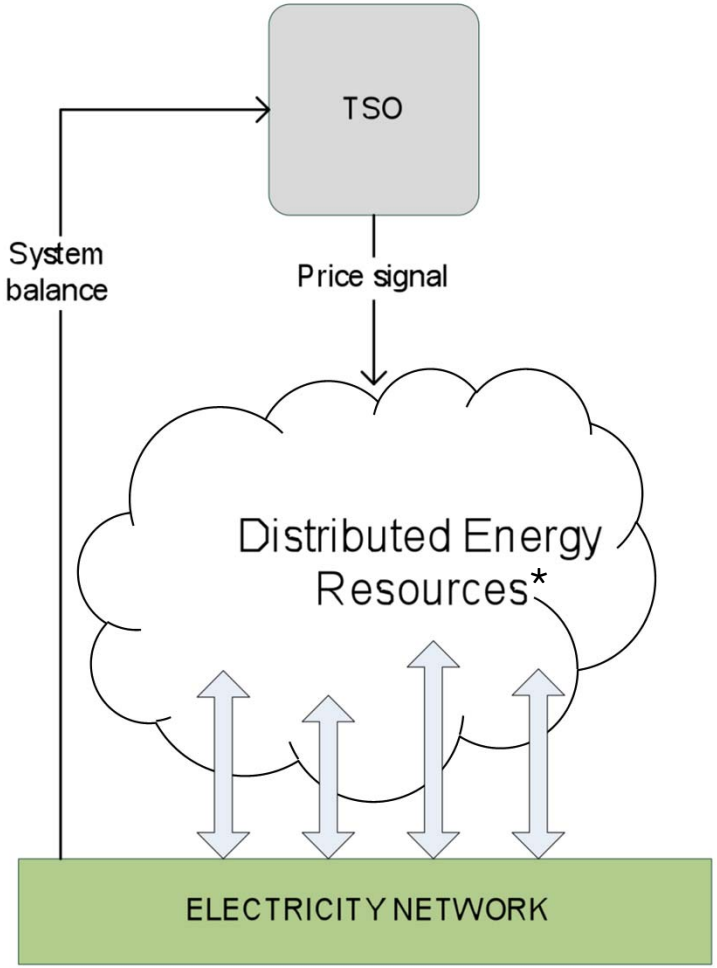
COOPERATION

Extention of the Market Solutions

True Market Integration of Smaller Units
Shorter Time Constants



The Fundamendal Idea of the EcoGrid EU Concept

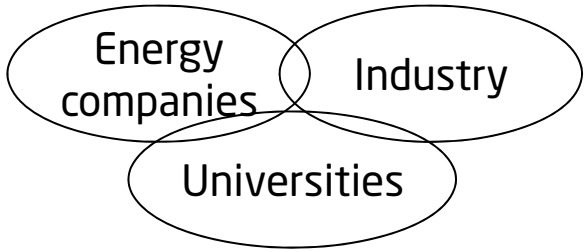


The market concept allows regulation of DER through price signal without direct measurement of the individual DER response

* Includes flexible demand

Bornholm as Smart Green Test Island
Perspectives

- **Test solutions in a real large-scale system with high share of RE**
  - Part of the interconnected system enables replication
  - Isolated operation possible (a true high RE case)
  - Typical system with its own characteristics

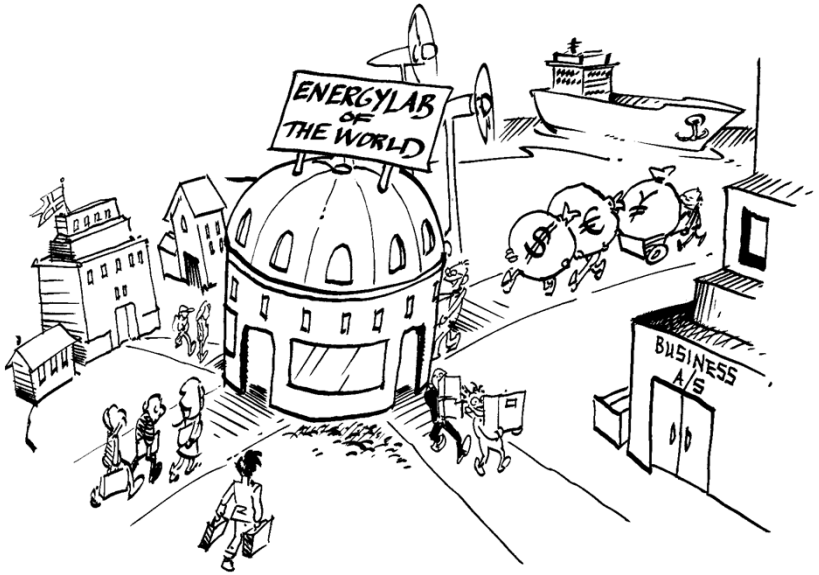


- **Synergy among multiple activities**
  - Measurements and models
  - Cost efficient development and test

- **A platform for collaboration**
  - Solve real problems together
  - International collaboration and solutions

- **Education of new generation of engineers**
  - Student projects

- **A role model for a future smart grid**
  - Showroom
  - Telling the "story"



Thank you!

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